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SOIL MICROBIOLOGY *

SOIL microbiology may be defined as that branch of science which treats of the micro-organisms in soils, their character, life-history and function and their relationships to the fertility or crop-producing power of the soil. It is not enough to isolate micro-organisms from the soil, to study them in pure culture, to characterize and classify them to define the science. The relationships of the micro-organisms to the crop-producing power of the soil is fundamental in the concept of the science.

It is quite generally known, by the soil microbiologist at least, that productive soils contain greater numbers of micro-organisms than unproductive soils and that those soil management practices which have proved to be effective in building soil fertility also stimulate desirable microbiological action in soils. However, to many who make a business of growing plants, even this does not indicate the very close relationship of the soil micro-organisms to the growth of plants. To appreciate fully the almost complete dependence of higher plants upon the soil micro-organisms one only needs to observe the growth of plants in a sterile system. In many cases it is impossible to grow plants to their normal, full development without the organisms, and where it can be done it is usually attended with great difficulty. Another example which emphasizes this interdependence of higher plants and soil micro-organisms is the fact that barren soils are also almost always sterile soils. A soil may contain adequate mineral plant food constituents and still be unproductive, unless it contains the proper soil micro-organisms.

Soil microbiology is a relatively new science, but youth in this case does not imply lack of development. It was just sixty years ago that Koch developed the gelatin plate method of studying micro-organisms and much of the foundation work of the new science was done during the next twenty years following this discovery. Nitrogen fixation by bacteria in association with leguminous plants was proved,

*Extract from an article published under the title of "Contributions to the Development of Soil Microbiology from the South Eastern United States" by Dr. F. B. Smith, Microbiologist, Florida Agricultural Experiment Station, published in *Science*, Vol. 96, No. 2483, pp. 95-98.

the causative organisms were isolated and described and artificial inoculation was practised during this time. Nitrogen fixation by the non-symbiotic bacteria was proved and the free-living nitrogen-fixing bacteria were isolated and described. The production of ammonia and nitrates was proved to be biological and the nitrifying bacteria were isolated and described. The physiological processes of nitrogen fixation, nitrification, ammonification and organic matter decomposition were established and the physiological groups of micro-organisms were recognized. The stage was set for exploitation and the development of trends in soil microbiological investigations.

The pure culture methods of study followed by the medical bacteriologist and the systematist were favoured by many and for a time extending into the first decade of the next century the favourite pastime of the soil microbiologist seemed to be the identification of new species. The determination of numbers of bacteria in different soils, at different depths and under various conditions received the attention of many soil microbiologists during the formative period. This phase of the science is still in the process of development and much of the earlier work on numbers and kinds of organisms in the soil can be profitably reviewed. Since much of this work was done a new concept of the soil body has been established. Relatively little of the earlier work was done on a soil-type basis. We know now that soils differ one from another and we do not expect to find the same microbiological characteristics in all soils. From the beginning the influence of the agronomist in shaping the direction of soil microbiological investigations was evident. This was a rather fortunate circumstance for several reasons. This influence figured largely in the present concept of the science and was a large factor in the rapid development of soil microbiology as a definite branch of science.

It is no longer considered adequate to study the soil micro-organisms in pure culture, important as that may be, but it is now regarded not only desirable but imperative to study the soil micro-organisms in their natural habitat. Biological interactions are known to be important and new techniques are being developed to study the soil micro-organisms as they live in the soil. In 1939 it was stated by a high medical authority that the most outstanding development in medical science that year was contributed by a soil microbiologist who discovered that certain of the pathogenic bacteria were killed by minute quantities of a substance produced by soil micro-organisms.

Since 1887, when Hellriegel and Wilfarth proved that nitrogen fixation was accomplished by bacteria in association with leguminous plants, the nature of the partnership of the bacteria with the higher plants, the benefit derived by the micro-organisms and the mechanism of the fixation of nitrogen have been questions asked by all and problems which have baffled the efforts of the soil microbiologist. In recent years considerable progress has been made in these investigations. The enzymatic nature of the process, the isolation of factors specific for nitrogen fixation, the effect of hydrogen ion concentration on respiration and growth of the organisms are recent advances to our knowledge of the subject. The new techniques now available and being developed bid fair to a clarification of the mysteries of the process. No complete review can be given here of all the outstanding developments in soil microbiology, even during the last decade. Enough has already been said, however, to show the great interest in the science, the progress that has been made and to indicate the future possibilities for the investigator with imagination and industry. It is not at all unreasonable to expect new soil management practices, cropping systems, rotations, more intelligent use of green manures, manures and fertilizers based on microbiological action in soils when sufficient information is at hand concerning the effects of these treatments on the complex soil flora and fauna and the biological interactions in the soil. . . In spite of all the work that has been done and which is under way, there are many unsolved problems in the field of soil microbiology. The inoculation of legumes has not been uniformly successful, even if it is one of the oldest applications of the science. Much information has been gained concerning the factors affecting the growh of the Rhizobia, but we still know very little about the relative efficiency of different strains of the organisms. Although a few studies have been made on the effects of certain organisms on the growth of Rhizobia very little is known concerning the relationship of these organisms with the complex flora of the soil. The presence of Rhizobiumphage has been noted, but only scanty information is available concerning the occurrence and action of this bacteriophage. In spite of all the work of the past years on the chemistry of nitrogen fixation much remains to be determined concerning the metabolism and functional relationships of the nitrogen-fixing micro-organisms. It is still uncertain whether the Rhizobia fix nitrogen apart from the host plant. Nodule formation is met with in many plants other than the leguminosae, yet it is not known definitely whether symbiotic nitrogen fixation occurs in all cases. The interactions of soil micro-organisms and the higher plants, of which mycorrhiza formation is another special case, is a field rich in possibilities. Since the soil micro-organisms are plants it seems logical that the biological tests for the availability of plant food constituents and the determination of the fertilizer needs of soil should be more satisfactory than chemical tests. Although several of these tests have been under investigation from time to time, no procedure has been developed which does not leave much to be desired. Soil microbiology is still a virgin field. Many of the earlier findings in other regions are still to be confirmed on American soil types.

THE BREEDING AND ARTIFICIAL INSEMINATION OF DAIRY COWS IN TRINIDAD, B.W.I.

BY

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Introduction

The Caribbean area consists of a number of islands, on most of which cattle are kept. On some there are a few hundred head, whilst others carry very large numbers. It cannot be said that the cattle are of high quality on the average; generally speaking they are neither good beef nor good dairy stock. Whilst there are some large herds, considerable numbers of cows are owned in ones and twos by peasants. To provide good dairy bulls for all these cows would be very expensive and would entail setting up a large organisation. The possibility of employing the method of artificial insemination appeared to be worthy of study as it would have many advantages were the method found to be practicable, either within the confines of one island, or for a group of islands.

Preliminary Studies in Artificial Insemination

In 1941 the writer was fortunate in meeting in Lima, Peru, Dr. Fred Mackenzie of the Utah State College of Agriculture, who is recognised as one of the foremost authorities and workers in the field of artificial insemination. As a consequence in the same year a post graduate student of the Imperial College of Tropical Agriculture, P. H. Richards, commenced a study of the methods of breeding dairy cattle in Trinidad and made an enquiry into the factors which affect the "settling" of dairy cows. Dr. Mackenzie very kindly assisted him with advice and the loan of literature, and is due many thanks for his kindly interest and helpfulness.

The practice of artificial insemination was new to Trinidad, and for various reasons it was decided to give the method a trial. An examination of the breeding records of dairy herds kept in sheds and permitted varying amounts of exercise daily revealed a somewhat low breeding efficiency. The causes were thought to be many: vaginitis is prevalent, and resorption of the foetus after the second month was suspected, and later confirmed.

Richards' work consisted in breaking ground, and he made a wide enquiry into factors which are concerned in breeding. Practical work involved the examination of many cows which were known to be shy breeders. Failure of some of these cows to come on heat was traced to arrested development of the *corpus luteum*. This condition may be corrected by suitable massage of the ovary per rectum. By this means a number of cows exhibiting anoestrus were brought on heat, and some of these were subsequently successfully settled either by the bull or by artificial insemination.

It was realised that this was not a real test of the value of artificial insemination; to use shy breeders only is not a fair trial of the system but at the time it was possible only in this way to secure the loan of dairy cows for the purpose. It should be noted that no breeding stock is kept at the College, the farm being very small indeed; in any case numbers of cows are needed for a trial.

The three largest dairy herds in the Island are under the management or supervision of professional veterinarians, their main interest naturally being the commercial success of the herds in their care, however achieved. Unfortunately they discountenanced the practice of the method of rectal examination which they felt should be reserved to trained men of professional standing. On account of this it was not then possible in every case to make an early examination for pregnancy via rectum. In view of the occurrence of resorption, a late determination of the results of service or of insemination admits of inaccuracy. There is, however, the possibility of other methods being worked out for determining pregnancy at an early stage. Richards, after manipulation of the ovaries, successfully inseminated a number of dairy cows known to be shy breeders the majority of which in due course would have been discarded. This experience made it still more necessary that the practice of artificial insemination be studied and demonstrated locally, as obviously both the public and the stock keeper would have to be convinced of its efficacy and value before it could be adopted as a practical measure. The former, because primarily it may have to provide the capital and the initial running expenses of insemination centres, and the latter because it will offer opportunities for the improvement of stock hitherto out of his reach financially. In passing I would remark that if the war has done nothing else for agriculture it has at least convinced the public that it has more than a shopper's interest in farm production. From now on agricultural questions will be of more interest and of greater importance to the public generally.

Before Richards finished his work in 1942, two new students namely D. A. McBurney and J. D. Yelf commenced work on two practical aspects of the problem. They confined their attention almost entirely to the cattle on the Government Stock Farm, St. Joseph. That dairy herd consists mainly of Friesland-Zebu crosses, and the difficulty regarding the early determination of pregnancy was partially met by the Government Veterinary Officer.

Collection, Preservation, and Use of Semen

Yelf worked mainly on a survey of the ejaculates of the bulls in use. At weekly intervals for a year (1942-43) semen was taken from the herd bulls available. The volume, initial motility, and spermatozoa count were taken, and, at first, before an irreplaceable electrode was damaged, the pH was determined.

Directly after collection undiluted semen was put in store; a comparison of the effect of quick cooling and slow cooling on longevity was made. Slow cooling proved superior. A large insulated test tube, in which small 8 cc screw top bottles were placed, each containing an ejaculate, was fitted into the neck of a thermos flask containing ice and water. The air in the test tube took 20 minutes to fall to O° C; the semen in the bottles cooled more slowly. When covered, the thermos flask and its contents was placed in an ordinary household refrigerator. Each day a portion of each lot of semen was examined for motility, and for concentration.

It was found that good semen, that is semen of high initial spermatozoa count and high motility, according to Herman and Swansons scale, would keep in useful condition for three days at least. Initial motility rather than spermatozoa concentration appeared to be the main factor indicating longevity of spermatozoa kept at about O° C. throughout the period of storage. The preservative effects of diluents were tested; centrifuged 13 day chick embryo apparently lengthened the life of spermatozoa.

The average volume of 3.63 c.c. of spermatic fluid per ejaculate indicates that the bulls were up to standard in this respect. The average of motilities for each bull used, ranged from 3.20 to 4.26; some of the bulls were poor in this respect. Out of 172 ejaculates counted, twenty-six showed a concentration below 300,000 spermatozoa per cubic millimetre and at the same time had a motility of less than 2.5. In addition 21 ejaculates showed a concentration of over 300,000 spermatozoa per cubic millimetre, but a motility of less than 3.5—the total of 47 poor ejaculates out of 172 examined represents 27%.

Semen of low quality is hardly likely to fulfil its mission. This low rating in conjunction with the known operating factors for low fertility in the cows will explain to some extent why so large an average number of natural services are required for each conception. For the whole herd, of the cows which conceive, approximately 58% do so at the first service, the balance of 42% do not at once conceive partly for reasons connected with the quality of the semen or the temporary sterility of the cows themselves.

An attempt was made to correlate the quality of semen from each bull with the climatic conditions prevailing at the time. No positive results were obtained from the locally bred bulls but an imported Friesian bull appeared to be greatly influenced by climatic factors—the volume and concentration of semen increased directly with increase in the rate of evaporation as measured by the white bulb atmometer.

This work has demonstrated that it is feasible to consider the probability of storage of semen in the wet tropics provided precautions are taken to prevent contamination of containers (steam and 65% alcohol were used, for the cleaning of instruments followed by rinsing with normal saline solution, and the disinfectant Amphyl for the glassware), and provided there are facilities for cool storage. Transport of semen was not attempted, but there is no reason to believe that a thermos flask properly fitted and charged could not be used for this purpose.

The use of dilutors, 4 of dilutor to 1 of semen, both in the preservation of semen, and in its use for service was tried. Two cows were successfully inseminated with diluted semen showing concentrations of 20,000 and 85,000 spermatozoa per cubic millimetre respectively. Some long periods of successful storage of diluted semen, initially of high quality, were recorded namely 13 and 15 days under our conditions.

Results of Inseminations

Mr. McBurney amplified Richards' examination of the last ten years records of the herd at the Government Stock Farm, and also carried out a trial over a period, involving the insemination of each alternate cow in the herd as it came on heat; the other alternate cows were bulled. This was done in order to demonstrate if possible the relative efficiency of the two methods, using the same herd and the same bulls.

There are several different crosses of *Bos indicus* (Indian Zebu) and *Bos taurus* (European, mainly Friesian) in the herd, and the cattle recorded were all kept with the object of milk production and treated uniformly for this purposes. Even the preliminary superficial examination of the records revealed irregularities in the reproductive cycles of the cows, and a complete analysis was deemed essential to ascertain whether such irregularities were great enough seriously to interfere with the breeding and management of the herd.

The record of the results of inseminations carried out by Richards, Yelf and McBurney were compared with the results of natural services taken by the same cows for the conception of their previous calf. Forty-three cows in all were inseminated by these three workers, the number of inseminations per conception averaged 1.30. The natural services needed by the same forty-three cows for the previous conception was 2.03.

When McBurney inseminated alternate cows it was found that for 16 cows 1.34 inseminations per conception were needed, whereas the 16 alternate cows which were served naturally required 2.20 services per conception. Three factors are noted as possibly explaining the above results:—

(i) The spermatozoa are placed in the cervix by insemination.

(ii) Infertility of the bull is avoided as the semen was examined before use.

(iii) Some diseases of the reproductive organs of the cow were detected before inseminating, and treatment given before the operation was performed.

As the bulls were the subject of examination by Yelf, the work of these men was complementary. McBurney noted that nearly all the cows came on heat during the night and early morning, and the duration of oestrus appeared very short. The cows were served or inseminated between 9.30 and 11 a.m. Four cases of vaginitis were found. One advantage of artificial insemination lies in the fact that the reproductive organs of the cow are readily examined before inseminating, whereas it is not usual to do this when natural services are offered. Furthermore small size peasant owned cows are not able to bear the weight of a heavy improved bull, even when assisted; no such disability attaches to artificial insemination.

In view of the partial sterility encountered it was naturally suspected that a number of cows would exhibit functional sterility; the ovaries showed lack of tone suspending ovulation, or the *corpus luteum* was persistent, this must be enucleated before ovulation may take place; or there may have been cystic follicles resulting in nymphomania. The practice of massage of the ovaries, expelling of the *corpus luteum*, or of hormonal therapy should perhaps be more general under our conditions. Pregnancy diagnosis at an early date, say between one and two months after service would help.

Analysis of Breeding Records

Following systems, mainly that of A. O. Rhoad, a close analysis was made of the breeding records of the herd and this revealed some interesting features. The records were taken from 1932 up to 1943, a ten-year period revealing the breeding histories of some 350 individual cows. The first "successful service" was marked, this is mentioned because from the record it appeared that many cows accepted service after they had conceived and were normally in calf, sometimes as late as six months afterwards. In such cases it was possible only to calculate the "successful service" by working 284 days back from the calving date.

The "Service Record" was obtained by adding up the number of actual services given per conception, excluding those taken after conception as mentioned. The "Service Period" was calculated from date of calving to the date of the next conception or fertile service.

Calving.—The total number of calvings in each of the months over the ten-year period was averaged per month. The herd is kept for the liquid milk trade and a reasonably uniform daily output is required. The calving peak, however, occurs in November, and the trough in July, there being over twice as many calvings in November as in July, the intervening months showing graded increases July up to November from both sides. Thus, despite the intention of the management to achieve a uniform monthly calving rate, some factor or factors intervened.

58.3% of the calvings during the ten years were the result of one service. By taking only these conceptions, thus presumably reducing the effects of sterility, the month of February showed up as the chief month of conception, shading down to June and remaining steady at about half the February rate until December. In January the rate rises steeply to its peak in February. The very humid rainy season lasts from May to December followed by less humid and drier conditions, accompanied by light breezes—which occur from January to April and into May. As the cattle are steadily fed and have some green food throughout the year, it perhaps is not the condition of alimentation but rather the effect of climatic which is operating.

41.7 per cent. of the calvings were the result of more than one service. Of the 350 individuals representing the herd throughout the 10 years, 58 head or 17 per cent. were removed from the herd because they were considered to have become permanently sterile. These cows were given every chance, they were persevered with on the average some nine months each, and received an average of 6.5 services during that time. Such a rate of discard for this reason alone is high, and augments the habitual replacement rate. A high incidence of tuberculosis was noted in the cows discarded for sterility.

The Service Period.—Is a term used to denote the period which elapses between the date of calving and date of subsequent conception, and is a good index of fertility, since a really fertile cow should calve once a year, having a service period of approximately 85 days. The average service period for the herd is 141 days, that is the average cow calves once in 14 months. Thus there is a considerable loss of time and therefore of production. Time of year or season does not appear to affect the length of the service period. The service period of the cows which calved or will calve within 12 months of the previous calving average 64.4 days, whereas the service period of the cows which calved or will calve later than 12 months from the previous calving averaged 205 days.

The Gestation Period.—This averaged at 284.4 days. Some abortions were recorded, but close examination of the records revealed that a number were not. It is important that the irregularities of pregnancy under the conditions obtaining in the wet tropics be studied. There is imperative need for veterinary research in the West Indies, and problems of management need much more careful study. Lack of sufficient exercise is thought to be one of the reasons why the fertility of the herd is reduced. The conditions under which dairy animals are kept in the wet tropics are unnatural enough.

Fertility of Different Breeds and Grades of Cattle.—The influence of Zebu blood in the Zebu-Friesian crosses in Trinidad was examined, the pure bred Zebu and the pure Friesian are both represented on the farm, as also grades from 1/4 Friesian to 7/8 Friesian-Zebu. The results obtained for the average service periods for these different breeds and grades of cattle are shown in Table 1.

Table 1

Grade	*Aver. service periods (days)*
Pure Friesian	236.1
7/8 ,, ...	176.4
3/4 ,, ...	164.1
1/2 ,, ...	131.5
1/4 ,, ...	114.4
Pure Zebu	100.1

Thus it would appear that the higher the proportion of Friesian blood the longer the service period.

With the service records, similar results were obtained. These are presented in Table 2. Here the relative average service records have been calculated by taking the average service record of the pure bred Zebu as 100.

Table 2

Grade	*Relative number of services*
Pure-bred Friesian	382
7/8 ,, ...	382
3/4 ,, ...	211
1/2 ,, ...	190
1/4 ,, ...	199
Pure Zebu	100

The difference in all these figures between the 1/2 bred and 3/4 bred Friesian is only slight. The figures for permanent sterility were highest in the pure bred Friesian and lowest in the Zebu.

Milk Yields.—The average milk yield per lactation of the various breeds and grades of cattle are shown in Table 3 :—

Table 3

Grade	*Average milk yield per lactation (lbs.)*
Pure-bred Friesian	2979
7/8 ,, ...	3612
3/4 ,, ...	4486
1/2 ,, ...	4316
1/4 ,, ...	3287

The pure-bred Zebu cows were not hand-milked, they nursed their calves. Table 3 indicates that there is again little difference between the 1/2 bred and the 3/4 bred Friesian.

From Tables 1 and 3, assuming an average gestation period of 284 days for each of the classes of cattle, it is possible to calculate the annual average yields of the different kinds of cattle and their daily overall average productions (*i.e* average productions over both milking and dry periods). These figures which are given in Table 4 suggest that the half bred is actually the most effective milk producer under Trinidad conditions. It is as good as the 3/4 bred and markedly better than the 7/8th or the pure Friesian.

Table 4

Calculated Average Production of Milk in Pounds per Head

	No. of cows	*No. of lactations*	*Annual average*	*Overall dairy average*
Pure-bred Friesian	12	44	2,091	5.73
7/8 ,,	16	47	2,861	7.85
3/4 ,,	43	120	3,655	10.01
1/2 ,,	96	287	3,796	10.40
1/4 ,,	11	71	3,124	8.56

Everything, therefore, seems to be in favour of experimenting further with the half-bred, endeavouring to fix a new breed with that proportion of Friesian blood. Not only is the half-bred apparently on the whole a better milk producer under local conditions than the grades with more Friesian blood in their constitution but it is also almost certainly hardier. During the early years of breed-building, the more frequent production of calves is also a very real advantage.

It is of interest to note here that at the Government Stock Farm, Shika, Nigeria, eight indigenous white Fulani cows bred from animals of the breed selected for milk, have averaged between 3,240 and 4,837 lbs. of milk during 4 to 6 lactations each. Five of these cows are the daughters of Stock bull No. 13. These eight selected cows average as well as the average of cross-bred and pure-bred Friesian cows kept for milk at the Government Stock Farm. It is common knowledge that a few cows of Zebu type selected and bred in India for milking purposes have reached the 10,000 lbs. mark. The well known Pusa herd is within measurable distance of the 6,000 lbs. average per lactation, and other herds not so long established as the herd at Pusa, are showing herd averages of between 3,000 and 4,000 lbs. per lactation.

Grades of milking breeds will have to be relied on to meet the growing demand for fresh milk in tropical areas, pending the evolution of a special type.

Future Investigations

The work which these students have carried out should be continued. Earlier in 1940 C. A. Walker carried out a survey of the methods employed by many dairy men in Trinidad in feeding their milking cattle. In the main they were an imitation of the methods employed by dairy farmers in dairying countries which could conveniently be followed in Trinidad. Much more enterprise in the use of Trinidad grown fodders and forages is needed, and this can be engendered by experiment and demonstration. There is much to be learned, and much closer supervision of the dairy herd is essential. It is to be hoped that the important work of research in dairy farming will be given far more attention in the future, especially as the population requires far more milk and milk products than are available at present. The cost of production is high, attention to detail and to all that touches the management of the dairy herds is imperative.

AVOCADO OIL

It is stated in a note by H. T. Love which appears in the 1942 Report of the Puerto Rico Experiment Station, Mayaguez, that although avocados are abundant throughout the American Tropics little commercial use has been made of them except as fresh green fruit. The oil of avocados contains appreciable quantities of vitamins A, D, and E and is said to have a high digestibility coefficient. These facts indicate that avocado oil would prove to be a desirable salad and cooking oil in those countries where avocados are produced abundantly and cheaply.

The edible portion of the fruit contains the following constituents: water 60 to 85 per cent., oil 5 to 30, proteins 1 to 3, carbohydrates 5 to 8, minerals 1 to 2, and crude fibre 2 to 7 per cent., depending upon the variety. After removal of the greater portion of the water and oil in the extraction process the other constituents are five to eight times more concentrated in the remaining cake than in the unprocessed fruit. This cake would therefore be valuable as a stock feed. With the prevailing shortage of vegetable fats and oils the use of avocado oil as a food and of the cake as a stock feed should have definite possibilities.

A limited amount of avocado oil is used in the cosmetic industry, where, because of its high skin-penetrating power and its ability to form fine emulsions readily, it is highly recommended. The present methods of preparing the oil for this use consist of slicing and drying the fleshy portion of the fruit and then extracting the oil by hydraulic pressure or with organic solvents, such as petroleum ether, ethyl ether, or benzene. Drying increases the cost of production, but it is not possible to extract the oil from undried fruit because of the high water content. Boiling the pulp with water, even under considerable pressure, releases the oil very slowly and gives poor yields, but freezing releases the oil so that it becomes available to organic solvents. This latter change is probably a result of two things, the dehydration of the cells containing the oil and a rupture of the cell walls. On the basis of this assumption a chemical treatment was sought that would produce the same results. Aluminium chloride and zinc chloride were tried and both gave satisfactory results. However, another method, using lime, was much cheaper and more practical. When treated with lime the pulp of Spinks avocados, known to contain 15.3 per cent. of oil as determined by the method of the Association of Official Agricultural Chemists, gave the following percentage yield on the basis of total oil: pressing 90.0 per cent., water flotation 82.3 per cent., and petroleum extraction by mechanical mixing 96.8 per cent.

When as little as 0.5 per cent. of lime, slaked or unslaked, was mixed with the fresh pulp which had been mashed and pressed through a fine sieve, the oil was released and the pulp set after standing a short time, so that the oil could be expressed in a hydraulic filter press, extracted with organic solvents by mechanical mixing, or obtained by floating off with water. Slightly higher concentration than 0.5 per cent. gave a product that could be more readily handled in the press. Avocado pulp treated in this way yielded a clear golden-yellow oil. This was bleached to a clear water-white oil by extended heating at 100°C. or by exposure to bright sunlight for several days. The latter treatment resulted in the development of rancidity, and some difficulty was experienced in removing the rancid principles by the usual caustic treatment. It is probable that the vitamin A content of the oil was materially reduced, if not entirely destroyed, by the bleaching treatments.

When the lime-treated pulp was extracted with petroleum ether or ethyl ether in a mechanical mixer the oil obtained was a clear green colour. The intensity of the green colour was influenced by the solvent used and by the length of time the lime-treated pulp was allowed to stand before extraction.

If use is to be made of the cake as a stock feed, the initial concentration of lime added to the pulp should be kept as low as possible, since a 0.5 per cent. concentration of lime in the pulp becomes 4 or 5 per cent. in the pressed cake. No extensive experiments have been carried out on the expressed cake obtained from the lime treatment, but it is known that stock will eat the cake provided the lime concentration is kept low.

INSECT PESTS OF CACAO IN THE STATE OF BAHIA, BRAZIL

BY

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(*Insect problems in agriculture in tropical South America are not well known to scientists in other parts of the world. We therefore welcome the following general account of cacao pests in Bahia, which ranks second among the cacao producing areas of the world. Senhor Silva, who recently spent a year at the Imperial College, makes interesting comparisons between insect problems in Trinidad and Grenada and those in Bahia.—Ed.*)

Introduction

BRAZIL is the second most important exporter of cacao in the world and the principal source of this product in the Americas. Production is surpassed only by the Gold Coast in West Africa.

Cacao in Brazil grows in the states of Amazonas, Bahia, Espirito Santo, Matto Grosso and Pará. Bahia contributes approximately 98 per cent. of the cacao output of Brazil, cultivation being mainly in the coastal region of the southern part of the state, comprising the districts of Ilhéus, Itabuna, Cannavieiras, Barra do Rio de Contas, Belmonte, Jequié, Santarém, Camamú and Una.

The first attempt to introduce the cacao tree into Bahia was made in 1746 by the French settler Luiz Frederico Warneaux, with seeds from Pará. The first important plantation was established in 1816 at Almada in the district of Ilhéus.

Bahia is today the principal cacao-growing region in Brazil with an annual production of about 120,000 metric tons. The type under cultivation belongs to the "Forasteiro" group, and comprises the main varieties "Comum", "Pará" and "Maranhão". More recently a few plantations have been established of the "Criollo" group, the trees being descendants of an original parent imported about 1907 from Ceylon by Leo Zehntner.

The Cacao Institute of Bahia was inaugurated in 1931 as an institution to aid planters in solving the problems of the cacao industry. Among various lines of work to be undertaken was the study of the insect pests of cacao, which has been carried out at the General Experiment Station at Agua Preta. In this paper the insects attacking cacao in Bahia are discussed and compared with cacao pests in Trinidad and Grenada. Suggestions are also made for their control.

Notes on Cacao Cultivation in Bahia

The establishment of cacao plantations in Bahia is carried out by the total felling and burning of the primitive forest, or the cacao is planted under the tallest forest trees after the lower vegetation has been cleared. Natural establishment of plantations in forest also occurs by means of cacao seeds scattered by a species of monkey known as the "jupará".

The plantations or "roças" are made generally under "contrato". In those established where the forest has been cut and burnt, the "contratista" interplants cassava, bananas, tannias, corn, etc., which serve as temporary shade for the young cacao trees and provide provisions for him and his family. The pickets are spaced three to four metres* from each other, and three seeds are planted at each picket. Permanent shade trees are provided by new spontaneous growth, but many "contratistas" do not like to use shade at all, believing that cacao under such conditions bears earlier than shaded cacao. Experiments carried out by Miranda (1938) at the General Experiment Station have shown that shade is vitally necessary for cacao plantations, and millions of seedlings and cuttings of *Erythrina vellutina* are being planted in the cacao zone for shading purposes.

On good and well-managed estates cutlassing is carried out once a year, but generally speaking most planters do not cutlass their estates. Pruning is generally badly done, and many planters either prune too heavily or not at all. The pruning of cacao is to be investigated at the General Experiment Station. Manuring, tillage, draining, control of soil erosion and other means of improving soil conditions are unknown among the planters. Experiments on some of these problems are being conducted at present but are not yet completed. At the suggestion of the writer experiments on manuring are being made with pen manure where cacao trees are declining in vigour and production, on the same lines as in the cacao-growing island of Grenada.

Harvesting of cacao pods is carried out by gangs of men with the "podão". The picking seasons are divided into "temporão" from March to July, and "safra" from September to November. During other months the harvest is known as "catagem". After picking, the cacao pods are put together in "bandeiras" and then in "rumas", and then opened by means of a cutlass and the beans extracted. The wet cacao is transported to the "côchos" in "panacuns", kerosene tins and bags carried by mules and also by canoes on the rivers.

* This spacing is equivalent to approximately 10 to 13 feet for which shade is necessary. When shade is not provided closer planting than this is required.—Ed.

The curing of cacao is done very much as in Trinidad and Grenada. Natural or sun-drying is carried out on "barcaças" or on "balcões", and artificial drying is performed in an "estufa". The dancing of cacao is a general practice. The bagging is done in sacks of four "arrobas", each "arroba" being equivalent to 15 kilos.

Major Insect Pests

The best and most recent account of the insect pests of cacao in Bahia is that of Bondar (1939a), published as a technical bulletin of the Cacao Institute of Bahia, in which are described 124 insects associated with the cacao tree, of which 101 are primary pests, 11 indirectly harmful and 7 beneficial.

CACAO THRIPS. The cacao thrips (*Selenothrips rubrocinctus* Giard) is a serious pest in Bahia. It is found attacking the leaves and pods in all cacao-growing regions, chiefly in those areas where shade is lacking. In some "roças" the attack is so heavy that many trees are partially defoliated. When attacked the pods became brownish, making it difficult to determine the stage of ripeness. Such a condition is known as "ferrugem" and the pods are said to be "enferrujado". The parts of the leaf attacked turn dark brown as if burnt, and this condition is known as "queima". It is of interest to note that in Trinidad and Grenada the attack is more often observed on the leaves, while in Bahia it is more common on the pods. In West Africa the attack is also apparently more commonly observed on the pods.

In Bahia this pest has existed since the early days of cacao cultivation, but the first serious outbreak was reported in 1917 when several plantations suffered great damage. Again in 1922 in the Mucury Valley, the cacao thrips appeared in great numbers causing serious damage in many plantations, but disappeared in the following year. The most recent serious outbreak occurred at the end of 1938, when there was also an important outbreak in Trinidad, according to information provided by Dr. E. McC. Callan. The writer believes that the abundance of this pest in Bahia is governed by two principal factors, viz., meteorological and biological. The meteorological factor cannot be discussed here because data are lacking. The biological factor must undoubtedly play an important part in the fluctuation of the thrips population. Some natural enemies, such as the predaceous thrips, *Franklinothrips vespiformis* Crawf., and the larvae of *Chrysopa* spp. have been reported as beneficial, but their value in control has not yet been definitely ascertained and there are no observations on their behaviour during thrips outbreaks in Bahia.

Besides the cacao tree the following plants are hosts for the cacao thrips in Bahia—"amendoeira" (*Terminalia catappa* L.), "abacateiro" (*Persea americana* Mill.), "goiabeira" (*Psidium* spp.), "cajueiro" (*Anacardium occidentale* L.), "roseira" (*Rosa* spp.), "urucú" (*Bixa orellana* L.), "colaeiro" (*Cola* spp.), "coca" (*Erythroxylum coca* Lam.), and "jambeiro" (*Eugenia jambos* L.).

"CHUPANÇA DO CACAU". The "chupança do cacau" is also known as "bexiga" and is a Capsid bug belonging to the genus *Monalonion*. This genus is represented by the species *M. bondari* Costa Lima, *M. flavisignatum* Knight and *M. bahiense* Costa Lima. There is still some confusion regarding the identity of the species of *Monalonion* in Bahia, and a thorough revision of the genus should be made.

The nymphs and adults of the "chupança" suck the sap from the cacao pod and the young shoots. When feeding on the pod, the tissue in the immediate neighbourhood of the point where the mouth parts are introduced becomes depressed and dark as soon as the sucking operation is completed. The writer believes that during the process of feeding some toxin is injected into the plant which causes the dissolution of the cells. On pods of 8 cms. or more in diameter these feeding punctures do not affect the beans, but wilting occurs when the insect attacks the cherelles or "bilros". Even in a fully grown pod, if the feeding punctures are numerous and very close together, the shell may break and the beans become worthless. In addition, the feeding punctures are avenues for the entry of fungus diseases so common on cacao.

Working on the ecology of this pest, the writer found that unshaded and weakened trees are more liable to be attacked than those which are moderately shaded. Bondar (1939, 1939a) states that the life cycle from egg to adult takes from 34 to 35 days. For *M. flavisignatum* the native host plants are *Begonia convolvulacea* D. C. and *B. vitifolia* Schot., for *M. bahiense* the wild host is *Hamelia patens* Jacq., and for *M. bondari* the native host plant is unknown. No parasites or predators have been observed on this pest in Bahia.

As far as is known this pest does not exist in Trinidad. Although specimens of *Hamelia* sp. were examined in that island, no species of *Monalonion* were found attacking it. In consideration of the serious damage caused by this pest in Bahia, where sometimes from 50 to 60 per cent. of the crop is lost, the writer drew the attention of the Plant Quarantine authorities of the British West Indies to the grave danger of its accidental introduction into Trinidad from South America.

"SAUVA" AND "QUEM-QUEM" ANTS. In Bahia there are two species of leaf-cutting or parasol ants, the "sauva" (*Atta cephalotes* L.) and the "quem-quem" (*Acromyrmex subterraneus* For. var. *bruneus* For.), which cause great damage to cacao.

The injury caused by the "sauva" ant to the foliage of many plants, including cacao, is well known throughout tropical America. In Brazil "sauva" ant control is a national problem, and it is not without reason that it has been said "Unless the Brazilians destroy the sauva, the sauva will destroy the Brazilians". The "sauva" ant in the cacao-growing region builds its nest on the surface of the soil, sometimes one metre in height and occupying from five to ten square metres in area. The cacao districts most infested by this pest are Ilhéus, Itabuna and Rio Novo. In some places the damage is so great that many trees do not recover and die out due to the continuous attacks, giving rise to the "clareiras" in plantations.

Another species of leaf-cutting ant is the "quem-quem", which is very common in the districts of Cannavieiras and Belmonte. This pest removes the young shoots, flowers, leaves, cherelles and epidermis of the pods, and this material is taken into the nest to serve as a substratum for the fungus growth which is used as food by the ant, in the same way as in the case of the "sauva" ant. The nest is built on the surface of the soil with pieces of leaves, often around the trunk of the cacao tree, on the branches of high forest trees among Bromeliads, or sometimes within the rotted trunks of felled trees.

"ENXERTO" ANT. This species, *Azteca paraensis* For. var. *nociva* Borg., ranks as a major pest of the cacao tree in Bahia. Besides the common name of "enxerto" ant, it is also known as the "mangue" ant. Not only is it a most serious pest of cacao in Bahia, but also of forest trees such as "genipapeiro" (*Genipa americana* L.), "arariba" (*Sickingia erubescens* All. & Sald, da Gama), "ingazeira" (*Inga edulis* Mart.), "corindiba" (*Trema micrantha* Blume), "samumeira" (*Sterculia excelsa* Mart.), "jindiba" (*Sloanea obtusifolia* Schum.) and various species of Myrtaceae, Moraceae, etc.

The "enxerto" ant feeds on the honey-dew produced by sucking insects such as tree-hoppers, scale-insects, aphids and white-flies. To protect these insects from their natural enemies the ant builds protective covers over them made of paper-like material. The ant, therefore, encourages the development of sucking insects which are pests of the cacao tree.

Direct damage occurs when the ant cuts the young shoots of the tree to obtain the gum-like substance which exudes from the wounds and which is used in building its nest. In the cacao tree as well as in forest trees attacked by this pest, the ends of the shoots are bare of leaves and very numerous, being somewhat broomlike in appearance, with a group of leaves arising in a cluster below the malformation. In such a condition a cacao tree can be detected among healthy ones even at some distance. By continuous attacks the cacao trees die out, giving rise to the "clareiras" which are increasing in cacao plantations in Bahia.

Within the nest of the "enxerto" ant are found seeds of epiphytic plants carried in by the ant. From these seeds arise plants, generally Orchidaceae and Gesneriaceae, whose roots make the nest secure and ensure a uniform humidity within the nest. In appearance the nest, which is protected from rain and sun by these epiphytes, resembles a large sponge, and sometimes reaches 40 to 50 cms. in diameter. It appears that the presence of these plants is essential to the development and life of the "enxerto" ant, the epiphytes and insects living in a form of symbiosis. The ant derives its common name "enxerto" from the presence of the epiphytic plants.

Minor Insect Pests

CATERPILLARS ATTACKING THE POD. The two principal caterpillar pests boring into the cacao pod are *Melanchroia mexicana* Guen. and *Stenoma decora* Zell. The latter is a new potentially important pest descovered by the writer (1938, 1939, 1943) and recorded for the first time as a cacao pest in Bahia. Another minor pest is the "traça do fruto", the caterpillar of the moth, *Marmara isortha* Meyr., which mines in the epidermis of the pod.

Various authors have cited the larva of the moth, *Myelois duplipunctella* Rag., as a pest of the cacao pod, boring through the pod wall and destroying the beans. The writer has bred this moth only from old rotten pods and, as far as he is aware, the larva is unable to bore into sound pods.

LEAF-EATING CATERPILLARS. Among the many leaf-eating caterpillars are those of the moths *Arsenura armida* Cram., *Pelochyta arontes* Cram., *Opharus astur* Cram., *Sylepta prorogata* Hmps., *Callicore meridionalis* Bates, *Halisidota maroniensis* Schaus, *H. sobrina* Mosch., *Belemnia ochriplaga* Hmps., *Automolis herois* Schaus, *Anacaria regulata* Fabr. and *Thecla* sp. With exception of *A. armida* Cram., which will be dealt with in detail in a later paper by the writer, the biology of the others has been described by Bondar (1937, 1938, 1938a, 1939a).

TREE-HOPPERS. Many tree-hoppers attack the cacao tree in Bahia. The more common are *Tragopa humeralis* Fairm., *T. nitida* Germ., *T. fulvovaria* Fairm., *T. auriculata* Oliv., *Membracis lunata* Fabr., *Horiola picta* Coq., *Bolbonota pictipennis* Fairm., *Hoplophora porosa* Walk., and *Aethalion reticulatum* L. All these tree-hoppers, with the exception of *H. porosa*, are attended by honey-ants of the genera *Dolichoderus*, *Azteca*, *Crematogaster* and *Cephalotes*. The nymphs and adults of the tree-hoppers remove a certain amount of sap from the cacao tree, but their attacks are confined to new shoots, flower-stalks, cherelles and stalks of cherelles. When the cherelle wall is heavily attacked the tissues become twisted and the future pod is misshapen, sometimes with cracks in the shell. In some cases the cherelle becomes worthless, because the beans do not develop. In some cacao trees attacked by tree-hoppers up to one-fifth of the total crop is lost.

In the genus *Tragopa* the female lays her eggs in incisions made in the more woody parts with the saw-like ovipositor. The incisions are made generally in young shoots and in the pod stalk; in the latter the sap is cut off and the cherelle or young fruit wilts. The wilting of cherelles resulting from attack by tree-hoppers is often mistaken for physiological wilting, and this should be borne in mind by those conducting physiological researches on the cacao pod.

Hoplophora porosa causes damage similar to *Tragopa*, but injury is usually confined to young shoots (Silva, 1939a). The females of *Membracis lunata* make incisions between the bark and the wood of young shoots where the eggs are laid. This species is prevalent in cacao nurseries and young plantations. *Horiola*, *Bolbonota* and *Aethalion* deposit their eggs superficially and cover them with a wax-like material, and no damage is caused in the place where the eggs are laid.

Leaf-eating beetles. Leaf-eating beetles are represented by the families Chrysomelidae and Scarabaeidae. Among the leaf-eating Chrysomelidae attacking leaves of cacao are *Nodonota theobromae* Bryant, *Colaspis trivialis* Boh., *C. flavicornis* Fabr., *C. auripennis* Germ., *Homophyla adusta* Har., *Oxygona* sp., *Exora obsoleta* Fabr., *Omaspides nigrolineata* Boh. and *Porphyraspis reis-magalhaesi* Bondar. Some species of Scarabaeidae, such as *Acanthocerus sequistriatus* Germ., *Cloetus globosus* Say, *Plectrus* sp. and *Cerapis* sp., are minor pests of the cacao tree.

Leaf-eating beetles, chiefly those belonging to the Chrysomelidae, are very abundant during the wet season, attacking young leaves from April to June and from September to December, when the trees are flushing. It appears that excessive rainfall favours the increase of these pests, for in dry years they are very scarce.

Weevils. For the systematic knowledge of the weevils or Curculionidae attacking the cacao tree we owe a debt of gratitude to Sir Guy A. K. Marshall, F.R.S., former Director of the Imperial Institute of Entomology, London, who has described many of them.

In the Otiorrhynchinae the following species are harmful to the cacao tree, *Hypsonotus frontalis* Marsh., *H. rhombifer* Marsh., *H. modestus* Marsh., *H. parceguttatus* Marsh., *Archopactus suavis* Boh., *Naupactus theobromae* Marsh., *Thegilis theobromae* Marsh., *Lasiopus cilipes* Sahl., *Lordops gyllenhali* Dalm., *L. aurosus* Germ., *Moropactus perfidus* Marsh. and *M. lepidotus* Marsh.

In the Cryptorrhynchinae the following are pests, *Chalcodermus marshalli* Bondar, *C. camposi* Bondar, *Conotrachelus costirostris* Boh., *C. curvicostatus* Marsh., *C. inconcinus* Boh., *C. mamilatus* Boh., *C. praeustus* Boh., *C. quadrinotatus* Fhr., *C. semicalvus* Marsh. and *Tylodes vallericollis* Marsh.

In the Hylobiinae the species *Arniticus bondari* Marsh., *A. spatalatus* Germ., *Heilipus bonellii* Boh., *H. clavipes* Fabr., *H. monitor* Pasc., *H. ocellatus* Oliv., *H. prodigialis* Germ., and *Acallestes camelus* Marsh. are injurious to cacao.

These weevils are only pests of cacao in the adult stage, and their biology is little known. The larvae of some of them have been bred in the laboratory from seeds and fruits of wild trees. From the viewpoint of control a knowledge of the natural host plants is very important, and work is being carried out on the larval habits of the weevil pests of cacao. The Otiorrhynchinae damage the leaves and young shoots. *Heilipus*, *Arniticus* and *Acallestes* damage the young shoots, cherelles and pods. *Conotrachelus* damages the young shoots and epidermis of the cherelles.

The "podador do cacau", represented by two species of *Chalcodermus*, was discovered and studied by Bondar (1930, 1939). The larva lives within newly-killed parts of the young shoots. To provide the dead shoot for the larva, the adult female makes with her proboscis a series of incisions in a circle round the shoot. This prevents the sap running above the incisions and the young shoot wilts and dies. In young trees the continuous pruning of the shoots gives the trees an irregular shape.

No method is known for controlling the weevils attacking Bahia cacao plantations. A more detailed ecological study of the natural flora of the cacao region, in order to discover the breeding places of these pests would be an important step towards understanding how to control them.

Aphids. The commonest aphid on cacao in Bahia is *Toxoptera aurantii* Boyer. This pest is very prevalent from October to December, attacking young leaves and shoots. During the rainy season aphids mainly attack the flower bud and if the infestation is heavy flower development is prevented.

Ants, such as *Azteca chartifex* For. var. *spiriti* For., *Crematogaster* sp., *Dolichoderus bidens* L. and *Solenopsis geminata* Fabr. subsp. *medusa* Man., protect the cacao aphids by driving away their natural enemies, and receive in exchange the honey-dew expelled by the aphids. Predators of cacao aphids in Bahia are the larvae and adults of the lady-beetle, *Cycloneda sanguinea* L., and the larvae of the syrphus-fly, *Baccha clavata* Fabr. Another natural enemy is the Braconid wasp, *Lysiphlebus testaceipes* Cress., an internal parasite of the aphids.

Scale insects and mealy-bugs. The following species have been reported attacking cacao by Bondar (1939a), *Ceroplastodes melzeri* Bondar, *C. theobromae* Bondar, *C. bahiensis* Bondar, *C. costa-limai* Bondar, *Saissetia hurae* Newst., *Coccus viridis* Green, *Aspidiotus destructor* Sign., *A. cyanophylli* Sign., *Pseudaonidia trilobitiformis* Green and *Pseudococcus citri* Risso.

The four species of *Ceroplastodes*, described by Bondar (1925), attack the twigs of the cacao tree under the paper-like protection made by the "caçarema" ant which nurses them. The green scale, *Coccus viridis* Green, attacks the young shoots and the leaves, being nursed by ants of the genera *Solenopsis*, *Crematogaster*, *Wasmannia* and *Azteca*.

Aspidiotus sp. and *Pseudaonidia trilobitiformis* attack the leaves but are not very common.

The mealy-bug, *Pseudococcus citri*, lives in trophobiosis with fire-ants of the genus *Solenopsis*, known as "pichichica" ants. *Solenopsis brasiliana* Sants., *S. bondari* Sants., and *S. edouardi* For. var. *bahiaensis* Sants. occur in Bahia. The attacks of the mealy-bug are mainly on the fruit, which may be covered by hundreds of individuals attended by as many ants. Besides the direct damage done by the mealy-bug, the "pichichica" ant prevents the picking gang from harvesting the pods due to its painful sting. In the absence of cacao pods the mealy-bug is carried by the "pichichica" ant to young shoots of cacao, or to the forest trees used as shade, such as various species of Myrtaceae and the "pau d'alho" (*Gallesia gorazema* Moq.). Extensive experiments on mealy-bug control with kerosene emulsion were carried out by the writer (1938), but the conclusion was that control by this means is too expensive for general use.

CACAO BEETLE. The writer had the opportunity of discussing with Dr. E. McC. Callan the question of the existence of the cacao beetle in Bahia, believing that *Steirastoma depressum* Fabr. existed in Bahia and attacked only weakened cacao trees. Material in the collection of the General Experiment Station, however, which had been identified by Dr. G. Bondar as *S. depressum* Fabr. and was labelled "damaging weakened cacao tree", did not agree with specimens of the cacao beetle in Trinidad. Two distinct species may be involved.

Bondar (1939a) states regarding *S. depressum* and *Trachyderes succintus* L.: "Both are common among us. . . . .This insect (referring to *S. depressum*) is not a pest of the cacao tree in Bahia". Costa Lima (1936) cited *S. depressum* as attacking "paineira" (*Pachira* sp.) in Sao Paulo, and "mongubeira" (*Bombax* sp.) in Rio de Janeiro, but no reference was given to attack on either weakened or healthy cacao trees. Further observations are necessary, and the writer hopes to be able to ascertain the true facts regarding the existence and habits of the cacao beetle in Bahia.

MISCELLANEOUS MINOR PESTS. The long-horned grasshopper, *Meroncidius intermedius* Brunner, causes damage to the cacao tree, especially to the bark of the trunk in which the female makes incisions with her sawlike ovipositor in which to lay her eggs. The larva of the weevil, *Erodiscus cinconia* Fabr., bores within the twigs of weakened trees, particularly when exposed to sunlight and attacked by other pests such as the cacao thrips.

The greenhouse thrips, *Heliothrips haemorrhoidalis* Bouché, causes injury similar to the cacao thrips. The "cupins", *Eutermes ripertii* Ramb. and *Kalotermes wagneri* subsp. *pedestrans* Silv. occur on cacao, the former constructing runways over the trunk of the tree and prevent emergence of the flowers. The "percevejos", *Neodine macraspis* Perty and *Mecistorhinus amplus* Walk., attack the young green shoots. The lantern-flies, *Phrictus quinquepartitus* Dist. and *Anormenis albula* Walk., are minor pests, as are also the leaf-hoppers, *Oncometopia marmorata* Fabr., *Rhaphirhinus fasciatus* Fabr. and *Copicerus* sp. The white-flies, *Aleurodicus cocois* Curtis, *A. neglectus* Quaint. & Baker, *A. pulvinatus* Maskell, *A. fucatus* Bondar, *Paraleyrodes crateraformans* Bondar, *Aleurotrachelus cacaorum* Bondar, *A. granosus* Bondar and *A. theobromae* Bondar, all attack the leaves of the cacao tree.

Control of Cacao Pests in Bahia

No practical means have so far been found of controlling the insect pests of cacao plantations in Bahia. Chemical methods of control are impracticable under Bahia conditions, due to (*a*) the large area covered by the crop, (*b*) topography of the land, (*c*) difficulty in obtaining and high prices of the materials and equipment required, (*d*) lack of skilled labour to carry out the work, and (*e*) small margin of expenditure available due to unfavourable economic conditions. These conclusions are largely based on observations made by the writer during five years' work in cacao plantations in Bahia.

Methods other than chemical control are suggested for the control of cacao insect pests in Bahia. These comprise cultural and biological methods. Cultural methods include the improvement of crop nutrition and soil conditions, the use of shade and pruning, the development of resistant varieties and other means, while biological methods comprise the use of insect parasites and predators.

Cultural and biological methods must be based on a sound knowledge of the ecology of both the crop and its insect pests, and may require continuous financial support until success can be achieved. Cultural methods of control have many practical advantages over chemical methods. Cultural methods generally (*a*) prevent insect attack, (*b*) incur little or no extra expenditure, (*c*) are easy to apply and (*d*) frequently involve no drastic disturbance of accepted agronomic routine. In general, with crops such as cacao, which are grown over large areas and are of low unit value, cultural methods are the only ones that can be employed profitably to control insect pests.

The nutrition and soil conditions of the cacao tree in relation to its susceptibility to insect attack should be investigated by a team comprising an entomologist, a plant physiologist and a soil chemist. In the case of the cacao thrips, many authors state that there is a correlation between the humus layer and thrips attack. In Bahia cacao plantations, for instance, thrips attack is commonly observed in places where the humus layer has been depleted as a result of unshaded conditions.

It is suggested that similar experiments to those of Andrews (1923), who showed that a high ratio of available potash to available phosphoric acid in the soil resulted in a reduction of attack by *Helopeltis theivora* Waterh. on the tea plant in Ceylon, should be carried out on *Monalonion* spp. in Bahia. Stephenson (1938) has already shown in Trinidad that the application of potassium either as ordinary potash manures or in culture solution reduces the attractiveness of cacao to the cacao thrips.

Another line of research which should be followed in Bahia is the development of resistant varieties of cacao. When in Trinidad, the writer saw something of the work of Dr. E. McC. Callan on the selection of varieties of cacao resistant to the cacao thrips. Callan (1943) has recently shown that thrips resistance occurs in cacao, and appears to be attributable to the resistance of the cacao leaf to puncturing.

The use of parasites and predators for the control of insect pests of cacao seems to be largely an unexplored field. *Dasyscapus parvipennis* Gahan was first recorded as a parasite of the cacao thrips in the Gold Coast by Cotterell (1927, 1928), and has since been introduced into the West Indies, where it has been successfully established in Trinidad, Puerto Rico and Jamaica. Adamson (1936) gives an account of the introduction of this parasite into Trinidad and of its life history, and describes the technique of breeding in the laboratory and liberation in the field. Dohanian (1937) also describes the life history and the technique of laboratory breeding. No indication, however, of any effective economic control of the cacao thrips by *D. parvipennis* has so far been observed in the West Indies. *Baryconus* sp. has been erroneously recorded as an egg parasite of the cacao thrips in Bahia, but is in reality a parasite of the eggs of a long-horned grasshopper attacking cacao. Work on the biological control of cacao pests is at present being attempted in the Gold Coast, where Mr. H. E. Box is studying the parasites of *Sahlbergella singularis* Hagl. and *S. theobroma* Dist., which cause damage there similar to *Monalonion* spp. in Bahia.

Summary

1. An account is given of the major and minor insect pests of cacao in the state of Bahia, Brazil.

2. The major pests comprise the cacao thrips (*Selenothrips rubrocinctus* Giard), the "chupança do cacau" (*Monalonion bondari* Costa Lima, *M. flavisignatum* Knight and *M. bahiense* Costa Lima), the "sauva" ant (*Atta cephalotes* L.), the "quem-quem" ant (*Acromyrmex subterraneus* For. var. *bruneus* For.) and the "enxerto" ant (*Azteca paraensis* For. var. *nociva* Borg.).

3. Notes are also given on cacao cultivation in Bahia, and suggestions made for the control of insect pests of cacao under Bahia conditions.

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Glossary

Abacateiro—avocado tree
Amendoeira—almond tree
Arariba—arariba tree
Arroba—an old weight equivalent to 15 kilos.
Balcões—drying trays
Bandeiras—small heaps
Barcaça—drying floor
Bilro—cherelle
Cajueiro—cashew-nut tree
Catagem—picking
Chupança—pod-sucker
Clareiras—open spaces in cacao plantations
Côchos—sweating-boxes
Colaeiro—kola-nut tree
Contrato—contract
Contratista—contractor
Corindiba—corindiba tree
Cupins—termites
Enferrujado—rusted
Enxerto—graft
Estufa—stove
Ferrugem—rusting
Genipapeiro—genip tree
Goiabeira—guava tree
Ingazeira—sackysac, pois doux
Jambeiro—rose apple, pomme rose
Jindiba—jindiba tree
Jupará—the monkey, *Potos flavus*
Mangue—mangrove
Mongubeira—monguba tree
Paineira—wild chestnut, wild chataigne, chataigne marron
Panacuns—baskets made from vegetable string
Pau d'alho—garlic tree, shallot tree
Percevejos—stink-bugs
Podador—pruner
Podão—cacao rod, cacao knife
Queima—burning
Roça—part of a plantation
Roseira—rose tree
Rumas—large heaps
Safra—harvest time, major crop
Samumeira—saltfish wood, red mahoe
Sauva—bachac, parasol ant
Traça do fruto—fruit-miner
Temporão—early harvest, minor crop
Urucú—anatto, roucou

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CONTROL OF THE WEST INDIAN DRY-WOOD TERMITE, CRYPTOTERMES BREVIS (WALKER)*

The West Indian dry-wood termite, *Cryptotermes brevis* (Walker), is possibly the most important species of destructive termite in the West Indies because of its ability to live in dry wood within houses and because it does not construct an exposed nest or tunnels, and is therefore very difficult to control.

The adults are frequently seen flying about lights at night. Those which are not killed by their many natural enemies crawl beneath or behind some article of furniture or pile of papers or books and start tunnelling into the material. Radios and picture frames are frequently attacked, as are large pieces of furniture such as bureaus, desks and pianos, and also parts of houses constructed of susceptible woods. Gradually the tunnelling consumes the insides of the various wooden articles until they are mere shells without strength.

Experience has shown that some woods are disliked or are unpalatable to dry-wood termites. A notable example is West Indian mahogany, *Swietenia mahogani*. Other more susceptible woods are sometimes treated with various solutions to reduce their susceptibility to both termite attack and decay, but some of these remedies are not entirely satisfactory, as the appearance, or some other character of the wood is adversely affected. As dry-wood termites attack wood which is not generally exposed to the rain, a satisfactory chemical repellent need not be insoluble in water and the treatment may be shallow in its penetration.

Tests were made with about 40 of the more common inorganic chemical compounds to determine which elements would most effectively repel termites when deposited on the wood in aqueous solution by dipping treatment. Small samples of the very susceptible wood of *Bursera simaruba* were dipped in solutions of various strengths for various periods of time and were then made available to the termites, along with untreated mahogany and other woods of known susceptibility for comparison. It was found that samples dipped for 10 minutes in a solution of approximately one-half ounce of either copper sulfate, zinc chloride, barium chloride, or cadmium nitrate per gallon of water became more resistant to termite attack than mahogany.

The practical importance of this finding is obvious. Treatment of new furniture and other wooden articles by dipping or by applying the chemicals with a brush previous to painting or varnishing will provide cheap protection. The added finding that arsenic is toxic but not repellent leads to the suggestion that the introduction of a 0.3 per cent. arsenic solution into the tunnels of infested wood might not only kill the present colony but prevent reinfestation.

*Abstracted from an article entitled "How to make wood unpalatable to the West Indian dry-wood termite, *Cryptotermes brevis* (Walker). I. With inorganic compounds" by Dr. G. N. Wolcott in *The Caribbean Forester*, **4** : 145-157, 1943.

DEFICIENCY DISEASES AND THE RÔLE OF THE "MINOR ELEMENTS" IN PLANT LIFE *

BY

T. E. T. Bond

"The study of the nutrition of plants has been pursued during the last forty years with great zeal and excellent results. The complete revolution which rational agriculture and forestry have experienced through the establishing of the theory of the nutrition of plants, proves how much has been accomplished in this department The most significant result of the development of the nutrition theory mentioned is met with . . . in the fact that we are now able to rear plants artificially—that we are in a position, with chemically pure water to which we add some few chemically pure salts, to rear artificially highly developed plants . . .—that from inconspicuous and often scarcely ponderable quantities of vegetable substance; quantities of it as large as we choose may be produced in this way." Thus wrote Marshall Ward in the 1880's in his translation of Sachs' famous "Lectures on the Physiology of Plants" (12). And indeed the theory of plant nutrition as it was then established was revolutionary enough. In these days we can hardly realize the change in outlook that it implied. Green plants were now known to depend for their food supply, not on the complex "organic juices" of the soil, but on such simple substances as the carbon dioxide of the atmosphere, water, nitrates, and certain inorganic salts in solution. Thus was inaugurated the age of artificial fertilizers—one might almost say the "NPK era" of agriculture—and, in more modern times, but in direct continuation of Sachs' water-culture method, the revived and fashionable interest in soil-less cultivation of "hydroponics" (7).

Unfortunately for modern agriculture, the "complete revolution" in agricultural practice that Sachs and his contemporaries viewed with so much justifiable satisfaction has had unforeseen consequences. One of the most significant of these (conditioned also by the increasing mechanisation of agricultural transport and machinery, and other economic changes) has been the rise to prominence of the deficiency diseases with the increasing recognition of the importance for plant nutrition of the so-called "Minor Elements."

The present article deals with a selection only of the various aspects of this recent development of the nutrition theory. Certain aspects which are not dealt with here, as for instance the more theoretical significance of the "Minor Elements" for plant metabolism, and their importance as affecting the health of the grazing animal, have already been briefly referred to.†

The "Minor Elements"

Sachs describes as necessary for the healthy development of his plants only "chemically pure water" with "some few chemically pure salts." In terms of the chemical elements involved his list of essentials, (*i.e.*, apart from carbon, hydrogen, oxygen and nitrogen) is a short one—"it is simply necessary that the nutritive mixture should contain the elements potassium, calcium, magnesium, iron, phosphorus, and sulphur, in suitable . . . . . combinations"—ten essential elements in all, of which three, namely, iron, magnesium, and sulphur, are usually regarded as "Minor Elements" (possibly also calcium should be included here), since they are needed in small amounts relative to the plant's much larger requirements of nitrogen (N), phosphorous (P), and potassium (K). The fact that the list of essential "Minor Elements" is now quite rapidly being extended is due to improvements in technique and to our changed ideas of chemical purity. Water culture experiments, to be really critical, now demand some of the most elaborate and highly technical refinements of method to be found anywhere in agricultural research, although for certain purposes the simpler methods are still useful. The best authenticated of the recent additions to the list of essential elements are boron, manganese, copper, zinc, and molybdenum (8), (2). Claims made with regard to some other elements are still open to doubt, while there may also be elements, including such well known ones as sodium, chlorine, and silicon, that are essential for certain plants only, but not for plant life in general.

By some authorities, the attempt is made to distinguish between nutritional elements, which are needed in relatively large quantities, or which are known to be required by the plant for direct incorporation into the tissues (as, for instance, magnesium enters into the composition of the green colouring matter, chlorophyll), and the so-called stimulative, catalytic, and prophylactive elements which fulfil other less obvious functions. However, it seems likely that, in time, most of these will be found to have some direct nutritional significance, so that this distinction will disappear. The criteria of essentiality as given recently by the foremost American workers in this field (1) are worth noting. They are three in number, as follows:—(*a*) Deficiency must be shown to prevent the completion of the plant's normal life cycle; (*b*) it must be specific to the element in question, *i.e.*, an element is not essential if it can be replaced by another; (*c*) the element must be required by the plant itself, not merely on account of its effect on the chemical or biological equilibrium of the soil.

* Reprinted from *The Tea Quarterly*, XVI, pt. I, pp. 9-15.

† *Tea Quarterly* Vol. XIII, pp. 148-152, 1940.

All the essential minor elements so far mentioned have been shown to be deficient in soils in various parts of the world and many different kinds of crops are known to be affected. Various examples of deficiency diseases will be mentioned in the course of this paper, although no attempt will be made to include more than a small fraction of those already recognised.

Quantities of "Minor Elements" Needed by the Plant

An outstanding feature of "Minor Element" nutrition is the extremely small quantity of the elements required. In fact, many of them are distinctly poisonous to plants if supplied in any considerable amount and this applies especially to the four more recently discovered essential elements boron, manganese, copper and zinc. It is easy to see how the necessity for these elements came to be overlooked for so long. Water culture solutions in any case are surprisingly dilute. Sachs' original solution, for instance, contained about 0.3 per cent. of dissolved salts, giving some 0.94 parts of potash (K o) and 0.14 parts of nitrogen (N) per thousand. The naturally occurring soil solution is still more dilute and it has been estimated to have a total concentration of about 0.1 per cent. of dissolved substances (11). Compared with these figures the concentration of the "Minor Elements" needs to be almost incredibly low. Thus, in a recent Australian paper (9) dealing with copper deficiency in oats and other plants, we read that considerable responses were obtained to quantities of that element corresponding to three millionths of a gram to the litre of culture solution—a concentration of 0.000003 parts per thousand. Notwithstanding, a deficiency of copper is the cause of a serious disease of oats and cereals generally—usually called "reclamation disease," from its common occurrence on recently reclaimed peat soils in Australia as well as in many parts of Europe. The observation that "reclamation disease" could be controlled by the application of copper sulphate was actually made several years before a conclusive proof of the essential nature of the element copper was forthcoming.

Some idea of the effectiveness of small quantities of the "Minor Elements" can also be gained from the applications necessary to cure deficiency symptoms in the field. One of the best known deficiency diseases in Britain is the disease of swede turnips known as "brown heart" or "raan" (5). This is particularly prevalent in Scotland and is cured by applications of 10-20 lbs. of borax (representing 1.15 to 2.30 lbs. of the element boron) per acre. This small quantity, to be applied evenly, must be mixed with dry soil or sand (or with other artificial fertilizers) so that the total amount reaches at least a hundredweight. It may be noted that, unlike the case of copper deficiency quoted above, the first field proof of the occurrence of boron deficiency was preceded by the proof of essentiality of the element, obtained from water culture experiments.

Some Examples from Tea

Tea in Ceylon is not known to suffer from any deficiency diseases, although a few years ago the suggestion was made that *phloem necrosis* might be a disease of this kind—perhaps due to a deficiency of boron. However, this view has received no support from experiments that have been carried out and need no longer seriously be considered (3). In other countries, the best known and most important deficiency disease of tea is the "yellows" disease, in Nyasaland, which is caused by a deficiency of sulphur. This disease was first reported in 1926, and the cause of it was not ascertained until Storey and Leach (13) published their account of it in 1933. Tea "yellows" is interesting as the first case of sulphur deficiency so far reported in the field: it is cured by the application of fertilizers containing sulphates or by the direct addition of sulphur in quantities as low as 24 lbs. per acre. The acute sulphur shortage of the Nyasaland tea soils cannot yet be fully explained, and Storey and Leach are careful to point out that full symptoms of sulphur deficiency are developed only in the presence of an adequate supply of the other necessary inorganic nutrients.

Interest in deficiency diseases was recently increasing in Java where serious symptoms of potash deficiency had become noticeable in certain districts. This was followed up by the Proefstation, West Java, and a full account, based on field observations and sand culture experiments, was published in 1940. The sand cultures were extended to cover certain of the recognised "Minor Elements" and in a later paper (4) various experimentally induced deficiency symptoms were described. Some of these are noted briefly below :—

Calcium.—Tea plants without calcium grow well at first but later develop pronounced symptoms especially on the young leaves, of marginal yellowing, spreading inwards between the veins and eventually becoming brown or "scorched." A downward curl of the apex and margins of the leaf also occurs.

Magnesium.—Deficiency symptoms are noticeable only on the older leaves, which become very pale yellow, only the veins remaining green. There may also be a light marginal scorch. The authors consider that this deficiency may occur in the field in Sumatra.

Sulphur.—Symptoms produced experimentally agree closely with the symptoms of "yellows" the plants remaining small with practically no flush, the leaves being mottled with yellow especially between the veins. Tea "yellows", is not considered likely to occur in the field in the Dutch East Indies.

Availability of the "Minor Elements" in the Soil

The occurrence or otherwise of deficiency diseases cannot simply be predicted from the amount of the different "Minor Elements" known

to occur in various soils, although in some cases such a general relationship can be shown to exist. Thus, in S. Ayrshire, Scotland, there is definite evidence that "brown heart" of swedes is less severe on those soils derived from rocks containing tourmaline, a mineral rich in boron (5) though in a very insoluble form. More commonly it is a question, not of the total amount, but of the "availability" of the element in question, as affected by certain other soil factors, the most important of which are (*a*) water relations, (*b*) pH and lime content, (*c*) soil micro-organisms. To a certain extent these three factors are inter-related, but it will be convenient to discuss them separately, in the ensuing paragraphs.

Rainfall, and the water relations of the soil, may affect the occurrence of deficiency diseases in two ways. Firstly, it is a matter of general observation that such diseases are more in evidence during drought and in dry seasons than with normal rainfall. Thus, severe attacks of "heart rot" of sugar beet (a boron deficiency disease corresponding to "brown heart" of swedes) may be expected when a rainy spring, which has led to vigorous growth and feeding of the young beet seedlings, is followed by a dry spell in summer when the plant's absorption of soil nutrients receives a check (8). Tea "yellows," also, is most in evidence at the end of the dry season, after which there is usually a gradual improvement up to the end of the rains (13). Secondly, the leaching effect of heavy rainfall needs to be taken into consideration. Deficiency diseases are usually more prominent on light, sandy soils, than on the heavier more retentive types, although actual differences in total nutrient content also play their part here. The best example of a "Minor Element" deficiency caused primarily by leaching is that of "sand drown" of tobacco, which occurs in the United States, Canada, and Nyasaland, and which is due to a deficiency of magnesium (8). Symptoms of this disease take the form of a severe chlorosis in which only the veins retain their green colour, while the curing properties of the leaf are also affected. Magnesium is one of the commoner soil elements, but it is also one of the most easily soluble and is quickly leached out of the surface layers. For this reason, it seems likely that actual deficiencies of this element in the soil may be much more widespread than is usually realized (8).

The reaction of the soil and its lime content are among the most potent factors affecting the availability of the minor elements. The two properties are so closely related that it is not easy to separate one from the other. In most cases, however, the actual occurrence of free calcium appears to be of more direct importance than the degree of alkalinity with which it is associated. Thus, deficiencies of boron, zinc and iron are frequently induced by lime, the elements though present in the soil being rendered insoluble or otherwise unavailable in the presence of this substance. Iron, especially, is a major constituent of soils and it is doubtful whether true iron deficiency is ever met with. Lack of this element results invariably in chlorosis, or pallor due to deficient development of the normal green colour, and the relationship to lime is now so widely known that this condition is commonly spoken of as "lime-induced chlorosis." In Great Britain, there is a definite risk of this disease in planting fruit trees on certain calcareous soils (8). As a preventative, the trees can be sprayed with iron sulphate solution, or this substance can be applied as a dressing on pruning cuts and other wounds. A more economic method of control is to grow cover crops under the trees, which, by their root action, are found to increase the availability of the iron already in the soil and hence counteract the harmful effect of lime. Still another method of increasing the supply of iron to the trees is by injection.

The importance of soil organic matter, and the micro-organisms which it supports, is receiving increasing emphasis in recent work on the deficiency diseases. The relationship is in many cases obscure and new interpretations of the observed effects are constantly being given. One or two examples will be sufficient here. One of best of these is the "reclamation disease" of cereals, already mentioned as induced by copper deficiency. This is usually associated with highly organic, peaty soils, and the beneficial effect of adding copper sulphate has been interpreted by various authorities as due to a transformation of the physical condition of the organic colloids leading to improved water relations, to precipitation or inactivation of an organic soil toxin or to the replacement of copper rendered unavailable by the action of anaerobic soil bacteria (8). Copper is, however, truly essential to plant life so that the last mentioned alternative may prove to be the most feasible. A well substantiated case of this kind is provided by Gerretsen's recent work (6) on the "grey-speck" disease of oats, also prevalent on reclaimed moor or peat soils, but associated with a deficiency of manganese. According to Gerretsen, the manganese is rendered unavailable in the first place by precipitation in an insoluble form through the activity of certain bacteria. The symptoms of "grey-speck" are induced in the plant, not as a direct result of lack of manganese, but as a result of the increased susceptibility of the roots to the invasion of bacteria from the soil. They do not occur in the same manganese-deficient soils after sterilization, *i.e.*, in the absence of bacteria. Gerretsen also showed, however, that even under aseptic conditions, normal growth was impossible without a certain minimum quantity of manganese, so that this element can be regarded as truly essential for oats (and other plants), in a direct sense as well as in the more complicated manner revealed by the occurrence of the "grey-speck" disease.

Diagnosis and Cure of Deficiency Diseases

In the foregoing examples it has been assumed that a deficiency of a given element can be recognised by the characteristic symptoms produced in the plant and that the treatment to be followed consists of a simple manurial application of a compound containing the element in question to the soil. In the majority of cases, particularly with annual crops as cereals and "roots," this is the only feasible procedure. So many of the "Minor Elements" are poisonous in all but the smallest amounts that it is rarely advisable to apply them to the soil until definite evidence of their deficiency has been obtained. Recently, some attempts have been made to test the soil in advance by using it for the growth of some simple organism, such as an alga or fungus, that will quickly complete its life cycle in the laboratory. Ordinary methods of chemical analysis would be too tedious and besides, they would not necessarily distinguish between "total" and "available" amounts of the element in question in the same way that the growing plant will. As an example of a microbiological test of this sort is the use of the fungus *Aspergillus* (a common mould) to test the sufficiency of available copper, in connection with studies on "reclamation disease"(8). The fungus is grown on a synthetic nutritive medium containing no copper, to which is added a measured quantity of the soil to be tested, when it is found that a black colouration of the spores denotes a healthy soil (containing 1 in 400,000 parts by dry weight of available copper), while brown and brownish-yellow to yellow spores respectively denote varying degrees of copper deficiency and of liability to the disease.

With perennial crops, particularly fruit trees, where the number of plants per acre is relatively small, and the crop from each plant correspondingly valuable, it becomes more important to be able to diagnose a deficiency at the earliest possible stage, *i.e.*, before the yield has been impaired. For this purpose, the method of direct injection into the plant is proving very valuable. Besides, by this procedure there is no danger of the element supplied being rendered unavailable, as it quite frequently is when added to the soil. Injection of woody plants has been known and practised for a very long time, for certain special purposes. In the fifteenth century, for instance, it was recorded that apples could be rendered poisonous by injecting arsenic into the trees at the time that the fruit was ripening. Other more innocuous ends have been served from time to time by injections of spices and honey to improve flavour in fruits, of dyes to colour flowers, and of preservatives to improve the injected timber (10). From Sachs' time, injection for curative purposes became increasingly common especially the injection of iron salts to cure the ubiquitous iron-deficiency or lime-induced chlorosis, already mentioned. The modern use of injection methods for the diagnosis of mineral deficiency diseases has been largely worked out by Roach (10) and his co-workers at the East Malling fruit research station in Kent. Roach's methods depend on injecting the test liquid in such a way that a limited part only of the plant receives it. This may be a single branch, leaf or even a part of a leaf. Any response that it induces, such as a slight change in colour or texture of the injected part, will then stand out sharply against the untreated remainder. Working in this way, unsuspected mineral deficiencies have been diagnosed in a week, or even less, and the existence of widespread and potentially serious malnutrition in the British fruit-growing industry has been demonstrated.

An interesting extension of the injection method has been to apply it to the injection of nutrient salts and other substances including disinfectants designed to have a specific effect in reducing the incidence of insect attack and of parasitic diseases. Further progress in this direction is to be expected in the next few years and some important changes in the practice of disease control in woody plants may be foreshadowed.

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MISCELLANEOUS NOTES

Physiological Researches in Cotton

The following account of some of the work carried out by the Physiology Department of the Cotton Research Station, Trinidad, appears in the 1943 Report of the Administration Council of the Empire Cotton Growing Corporation. The problems investigated during the year included (1) water content of the leaf, (2) mineral nutrition in response to climate, with particular reference to the development of leaf, stem and root, (3) methods of diagnosing mineral deficiency, and (4) seed storage.

The work on the water content of the leaf has suggested a method for measuring the stability of the living protoplasm. It seems that protoplasm developed under uniform conditions of humidity is less easily altered than that developed under fluctuating conditions. The stability of the protoplasm appears to be related to conditions of senescence and health of the plant, and may be of importance in connection with work on susceptibility to insect and fungal attack.

There are indications that the plant's requirements for a particular element may vary in response to climate. Thus phosphorus appears to be required in greater quantities under dry, sunny conditions than under moist, shady conditions, whereas the plant's potassium requirements appear to be independent of such factors. Phosphorus tends to develop the top of the plant at the expense of the root, while potassium has the reverse effect, but these reactions may be profoundly modified by water supply.

It has already been found that potassium affects the rate of carbohydrate production in the leaf and this finding has now been utilised in a rapid method for diagnosing potassium deficiency using the disc technique. Briefly, discs from potassium-starved plants respond to added potassium by an increased production of material (dry weight), whereas potassium-rich discs do not so react. An investigation on the partition between crystalloid nitrogen and protein nitrogen in the leaf has suggested that it may be possible to judge nitrogen sufficiency or deficiency from the level of concentration of the crystalloid nitrogen.

Seeds stored for five years under 50 per cent. humidity still retain to a large degree their power of germination, whereas storage at higher or lower humidities has reduced it considerably.

* * *

The Food and Feeding Habits of *Antestia* in Kenya

In an article by R. H. Le Pelley published in the *Bull. Ent. Res.*, 33, pp. 71-89, it is shown that the *Antestia* bug will feed on any part of the coffee tree though it cannot be brought to maturity on red berries or leaves alone. The damage is more extensive and severe than any single writer has recorded. Even a few *Antestia* can cause an appreciable loss because of inoculation with a berry-destroying fungus. Although the presence of four *Antestia* per tree is usually the maximum allowed, the loss at this figure is not negligible and it would often pay to control them at a lower figure. On a research station a maximum of one bug per tree is regarded as the limit. Large green berry food is essential to normal life and reproduction, a fact of importance, since this does give a semblance of a breeding season. The large populations which will be present when the berry is ripe if not previously checked, will do little harm at that time since they feed on the berry pulp. The damage will occur when the crop is removed and heavy feeding occurs on the new shoots. The cropping capacity of the tree may be destroyed for more than one season. In connexion with the necessity of the large green berry for reproduction it is clear that intermittent flowering is a disadvantage since it enables the life cycle to be maintained without a break. Cultivation practices, therefore, from this point of view should aim at securing a single heavy flowering. The dropping of young green berries after attack is not due to injury inflicted on the stalk, which in fact may not have occurred, but is a response by the plant to an interruption of normal growth due to insect feeding. Confirmation was obtained that abnormalities such as multiple branching are a result of the feeding of *Antestia*.

* * *

New Synthetic Rubber

A new speciality rubber known as 'Paracon' has been developed by the Bell Laboratories, which looks and feels like ordinary rubber and resembles it fairly closely in mechanical properties (*Bell Lab. Rec.*, 20, No. 9; May 1943). It has a higher resistance to damage by oil or petrol and is better than natural rubber in resistance to heat, light and oxidation, although inferior to it in resistance to steam alkalis and acids. 'Paracon' can be worked with ordinary rubber machinery. In its raw state it is highly plastic and unusually well adapted to moulding into intricate shapes and to use in producing rubberized fabrics. 'Paracon' does not compete with other synthetic rubbers for its basic raw materials since the chemical intermediates required for its production are derived by other trains of chemical processes. For its synthesis it uses materials derived from agricultural products and coal products, or from coal and petroleum sources, and in each case by a variety of different chemical processes. The equipment for manufacturing 'Paracon' differs from that required for synthetic rubber production and, consequently, the new material can add to the present supply of rubber substitutes without interfering with the production of those already under way. The synthesis of 'Paracon' was accomplished by Drs. C. S. Fuller and B. S. Biggs of the Bell Laboratories and their associates. (*Nature*, Vol. 152, No. 3854, 1943.)

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Intake of Plant Nutrients by Tobacco

Data on the chemical analyses of tobacco leaf samples are presented in the Annual Report for 1942 of the Cawthron Institute, Nelson, New Zealand. In the early growth stages of the tobacco plants, the leaves contained comparatively high percentages of different food constituents, *e.g.* nitrogen (N) 3.67 per cent.; potash (K_2O) 4.98 per cent.; phosphoric acid (P_2O_5) 0.84 per cent. The percentages fell considerably at later growth stages. At the time when the harvesting of the plot commenced the figures were nitrogen (N) 1.84 per cent.; potash (K_2O) 3.65 per cent., phosphoric acid (P_2O_5) 0.57 per cent. on the dry matter basis. The total quantities of plant foods taken up by the plant, including leaves and stalk were nitrogen (N) 40.5 lb.; potash (K_2O) 82.8 lb.; phosphoric acid (P_2O_5) 13.8 lb., and magnesia (MgO) 11.2 lb. per acre. The importance of adequate nitrogen and potash in the manurial treatment of tobacco is well illustrated by the analytical data.

Approximately 50 per cent. of the total growth is represented by stalk and small leaves unsuitable for harvesting. This portion of the crop is frequently ploughed into the soil, and must aid considerably in maintaining reserves of plant food. Analyses show that the stalk and unharvested leaves contain the equivalent on the acre basis of superphosphate 40 lb.; sulphate of potash 75 lb.; ammonium sulphate 112 lb.; and dolomite 30 lb.

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Protein Concentrates from Grasses

There is at present a marked shortage of concentrates high in protein value available for consumption by farm animals. One of the most abundant sources of protein is grass, only part of which is used for pasture, hay or silage. If the remainder could be converted economically into a concentrated non-perishable form of protein it might be valuable in relieving the present shortage of protein concentrates.

Methods of extracting protein from biological substances may be found in the literature, but to the author's knowledge none has been made use of in preparing proteins from forage crops on a large scale. The author has made several preparations on a laboratory scale, an example of which is given here.

Dried ground grass was extracted overnight at room temperature with 0.25 normal sodium hydroxide and then filtered through cheese cloth. The filtrate was brought to pH 3.6 with hydrochloric acid and a precipitate was filtered off, dried and ground. The precipitate, dark green in colour and with a grassy flavour, contained 58 per cent. protein on the dry basis, 6 per cent. ash and less than 1 per cent. of lignin and cellulose. It also contained 440 p.p.m. of crude carotene, but this amount decreased during laboratory storage. Based on a ton of dry grass the yield of this substance was about 285 pounds. The grass residue, yielding about 875 pounds per ton and still containing .44 per cent. of the original protein, appeared to be a fair quality stock feed.

Extraction of the protein concentrate with 95 per cent. alcohol removed about 20 per cent. of its dry weight but only 4 per cent. of its total nitrogen. This final product was dark in colour and tasteless and contained over 72 per cent. protein on the dry basis. Its calculated yield per ton was 220 pounds.

It is suggested that either the crude or the extracted product could be made from surplus forage, or forage otherwise wasted, and if economically produced should be useful in supplementing present stocks of protein concentrates, particularly for poultry and hog rations. (J. T. Sullivan, U.S. Regional Pasture Research Laboratory, State College, Pa. in *Science*, Vol. 98, No. 2547.)

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Preparation of Compost from Wastes by "Hot Fermentation"

According to a paper published in *Proceedings of* 10th *Annual Convention Sugar Technologists' Association, India,* Part II, composts prepared from press mud, cane trash, and bagasse by aerobic fermentation, or by the Fowler activated compost process give a satisfactory manure but are too costly because of the amount of labour required for periodical turning; also, in these processes there are large losses of dry matter and nitrogen. Encouraging results were found however in the following hot fermentation process: press mud, cane trash cut in lengths of 2 to 3 inches, and bagasse (all these materials being air-dry) are mixed and made into a slurry with cow dung and molasses; a ratio of 3.1 of press mud to trash and bagasse is satisfactory; the dung and molasses are used in the proportion of 2 per cent. each. No turning was done, but the mass was kept moist by sprinkling with water when necessary. The best results were obtained by packing the material loosely in trenches 6′ × 4′ × 3′. After exposure for 7 or 8 days the heaps were covered with mud paste, thus providing a condition for an aerobic fermentation. In 7½ to 9 months the operation is finished; the amount of dry matter lost was from 18·6 to 21.3 per cent. The average nitrogen content of the compost was between 1 and 2 per cent. Only around 9 per cent. of the original nitrogen was lost as compared to losses up to 25 per cent. by other methods.—(*Sugar*, XXXVIII, 9, 1943.)

The Editor is prepared to consider signed articles for publication in *Tropical Agriculture.* Such articles should normally vary between **1,000 to 6,000 words and may be illustrated if desired.**